questionnaire above, shows some wavering in the answers, even though the interval of two months was probably too short for complete forgetfulness; in most cases, however, the principal ratios of answers were not materially changed, and it is believed that they are substantially true. The inability of some respondents to tell how they recall a forgotten name, or how they set themselves to work when disinclined, shows that these questions approach the limit of casual introspection. The questions in Group IV met with the most ready and satisfactory answers. The respondents seemed always sure that they were making truthful reports, the recollections were interesting to them, and they were glad to make any contributions to a better understanding of the child.

In general, the questionnaire seems to the writer more valuable for the suggestions it gives the questioner than for its strictly scientific results. Each group of this study has suggested some problem for further investigation by experimental methods.

IX. The Memory After-Image and Attention.

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The memory after-image is familiar to all who busy themselves with psychology; and many others have casually noticed it in their ability to count clock strokes from the beginning, after a number have already passed, or to pick up the whole of a sentence whose beginning has been neglected. The experiments of this paper were undertaken to determine, if possible, the duration of images of this kind.

A prime difficulty is to separate the simple persistence of the image (due, perhaps, to the native retentiveness of the nervous substance) from its continuation in associative memory. It is possible to avoid the latter by experimenting with completely distracted attention; for what is received with complete inattention forms few associative bonds, or none at all, and runs its course of gradual extinction without interference. The state of the image during the fading out can be discovered by requiring the subject at a given signal to turn his full attention upon it and to endeavor to reproduce it. The degree of his success will indicate the condition of the image. It is probably impossible, under ordinary circumstances, to secure perfect distraction, and, even if it were secured, it might not pre-

vent the formation of all associative bonds. Absolutely perfect distraction was not secured in the experiments about to be described; they were made, however, under as near an approximation to that condition as the experimenters were able to secure.

As a means of distraction, the loud reading of letters pasted on a revolving drum and seen, one at a time, through a hole in a screen, was first tried, but proved itself less effective than the reading of interesting stories in a loud voice and with the greatest possible rapidtiy. The image used was that aroused by the pronunciation of a group of three digits. When the subject was well underway in his reading, the digits were announced by the operator, the three occupying about two seconds. After a determined interval, at a signal from the operator (a tap on the table) the subject ceased reading and endeavored to recall the digits that had been given. The intervals were 0, 5, 10, 15 and 20 seconds. One hundred trials each were taken at these intervals, on each of two subjects, *S* and *D*, each serving alternately as subject and operator. At beginning, both subjects were somewhat experienced in this sort of experimenting and the trials, on different intervals, were so mixed as to exclude as far as possible the effects of both practice and fatigue. In spite of strenuous effort to concentrate on the reading it was not always possible to prevent a return of the digits to consciousness before the operator's signal and this difficulty increased with the increase of the interval. A record of the cases in

TABLE I.

Involuntary Return of Digits.

	5 Secs.	10 Secs.	15 Secs.	20 Secs.
SUBJECT S.				
No return,	47	29	22	19
One return,	50	67	66	54
More than one return,	3	4	12	27
SUBJECT D.				
No return,	40	36	15	15
One return,	56	56	60	75
More than one return,	4	8	25	10

which such a return occurred was kept and is summarized in the table above. Since 100 trials were taken for each subject,

with each interval, the figures represent percentages also. At the zero interval the reply of the subject followed immediately on the announcement of the last digit, and no time was given for the involuntary return here considered.

The strong tendency which this table shows for the image to thrust itself into consciousness, was probably due in part to the knowledge that its recall would presently be required; it testifies, in other words, to a partial division of attention. It is probably due in part, also, to the general tendency already often observed in both mental images and attention to a periodic rise and fall. When the original image of the digits was clear, the tendency to return developed almost at

TABLE II.

Decrease of Correct Replies with Increase of Interval.

SUBJECT S.

	0 SECS.[1]			5 SECS.			10 SECS.			15 SECS.			20 SECS.		
	Total Number of Cases.	Number Correct.	Per Cent. Correct.	Number of Cases.	Number Correct.	Per Cent. Correct.	Number of Cases.	Number Correct.	Per Cent. Correct.	Number of Cases.	Number Correct.	Per Cent. Correct.	Number of Cases.	Number Correct.	Per Cent. Correct.
No return,	100	56	56	47	5	9	29	0	0	22	0	0	19	0	0
One return,				50	7	14	67	1	1	66	1	1	54	1	

SUBJECT D.

No return,	100	96	96	40	24	60	36	10	28	15	0	0	15	0	0
One return,				56	40	71	56	17	30	60	7	12	75	7	9

[1]With this record at the zero interval may be compared the following percentages of correct replies in the preliminary experiments, gotten by observers *D* and *A*, with no distraction (ordinary memory span) and with the distraction of reading letters from the revolving drum, in which case there was no interval between the pronunciation of the digits and the subject's response. The figures in parenthesis give the number of trials on which the percentages are based.

	NO DISTRACTION.			READING FROM DRUM.		
Subject.	8 Digits.	9 Digits.	10 Digits.	4 Digits.	5 Digits.	6 Digits.
A	100 (4)	78 (23)	31 (26)		53 (31)	7 (16)
D	80 (20)	63 (42)	8 (9)	74 (49)	27 (28)	26 (12)

once; if this was successfully resisted, the chances of complete exclusion were much increased. In what terms the return occurs—auditory or motor, or both—would be interesting to know, but cannot be stated with certainty; subject *D* is inclined to believe it motor in his case. Frequently, when there was no actual return of the digits, the subject was unmistakably conscious of their presence and their struggle for recognition, and by redoubled efforts at reading was able to prevent their re-entrance. This tendency to immediate and repeated return is undoubtedly of the greatest importance in ordinary memory. It is in this way that the original memory after-images are caught into the conscious memory trains and made recallable.[1] If no such return takes place a few seconds suffice to obliterate the image. A single return prolongs its existence, but for a few seconds only, as is clearly shown by Table II.

The table shows that under the conditions of these experiments the memory after-image does not last fifteen seconds in a reproducible condition, unless it is freshened by a re-entrance into consciousness. If it returns a single time it may outlast twenty seconds, but not often.

The table also shows a considerably greater persistence of the image in the case of *D* than in that of *S*, and the ordinary memory-span tests with *D* (see note to Table II) indicate a high retentiveness, but the chief cause was probably a less complete abandonment to the reading on his part. This was the impression formed during the experiments and is corroborated by the large number of *S*'s incorrect replies with the zero interval, where lack of retentiveness would play a small part. This can only mean that a certain minimum of attention is necessary for the original registry of the image, failing which its persistence is considerably abbreviated. During the experiments the subjects noticed differences in the vividness of the original registry, and found an extra effort at concentration necessary during the pronunciation of the digits, an effort which the operator also could often observe in the increased loudness of the voice of the reader. The anouncement of the digits diverted a certain portion of attention to them, which, when the experiment was successful, was small and instantly withdrawn. The effect of this partial attention

[1]The much greater persistence of what has been consciously in mind was also unexpectedly testified to by the errors made. Numbers accidentally met in the reading were apt, unintentionally, to take the place of forgotten digits in the test groups. This was also the case with numbers once used by the subject in replying. In one series of twenty groups, for example, the digit four was actually given five times, but occurred in the replies seventeen times.

is perhaps in the nature of a repetition, at least both subjects found it difficult to distinguish between repetition and good registry. The effect was most marked when the announcement of the digits occurred during a necessary pause in the reading. From all this it is therefore clear that the durations shown in Table II are in excess of what might be expected with perfect distraction, were that attainable. They represent a limit below which the duration of the simple memory after-image falls. With perfect distraction the subject ought to be unable, after a very brief interval, to say whether or not any digits at all had been announced.

A group of digits has, of course, a shorter duration than the single digits that compose it and is harder to reproduce. This is evident on a comparison of Tables II and III, in the latter of which is given the percentage of right answers for the digits in the first, second and third places. All replies (except those which had been preceded by more than one involuntary return of the digits) were used in making this table.

TABLE III.

Percentage of Right Answers for Different Parts of the Group.

	No Return.			One Return.		
	1st Digit.	2d Digit.	3d Digit.	1st Digit.	2d Digit.	3d Digit.
SUBJECT S.						
5 Seconds,	14	29	87	20	24	80
10 Seconds,	24	13	27	5	14	73
15 Seconds,	9	13	31	7	10	60
20 Seconds,	5	10	15	14	9	40
SUBJECT D.						
5 Seconds,	70	70	95	78	78	95
10 Seconds,	30	41	83	62	39	76
15 Seconds,	20	6	46	31	21	75
20 Seconds,	10	10	5	29	17	66

The images of the separate digits evidently follow the same general course as the groups, but more slowly. Unless they get a recall, their chances of surviving fifteen seconds are, however, not very great. As regards the relative persistence of different parts of the groups, the table shows that the last

digit is more persistent and that there is little difference between the other two—a slightly greater persistence for the second in case of *S*, and for the first in case of *D*.

In conclusion, a few words may be added to show the relation of these experiments to those previously made by others. The term "memory after-image" (*Erinnerungsnachbild*) was introduced by Fechner,[1] who records observations on visual memory after-images. Exner[2] has described the same, under the name of the "primary memory-image," and gives examples for both sight and hearing. He remarks that the image vanishes in the course of a few seconds, if not caught by attention. Many experiments have been made on the simple memory span, with digits, letters or nonsense syllables. They have shown that, under favorable circumstances, groups of eight or ten members could be correctly reproduced. If the members of the groups were separated by one second intervals, this would show that in eight or ten seconds' time some of the members fall out of memory, and in even less time than that, for the errors are more frequent with the middle members of the group than with the first. The most elaborate experiments by this method were those made in Wundt's laboratory by Dietze.[3] In these experiments groups of metronome ticks were compared with each other, on the supposition that accurate comparison is possible only when each group can enter consciousness as a whole. The size of the largest groups that can be accurately compared would then give the size of the greatest groups that can be taken into consciousness entire, *i. e.*, the groups in which the first member given is just fading out of memory when the last member enters. The supposition on which these experiments were made has been criticized, but apart from that they do not give sure determinations of the duration of the memory after-image, because of the very great effect of the rate at which the ticks are given and the tendency to rhythmical grouping of them. The experiments on memory-span have generally been made with full attention; Münsterberg,[4] however, worked with attention distracted by solving arithmetical problems aloud, but used his results for other purposes than the measurement of the duration of the memory after-image. The experiments of Wolfe[5] on the memory of

[1] Elemente der Psychophysik, II, 491 ff.

[2] Hermann's Handbuch der Physiologie, II, ii, 282, quoted by James, Psychology, I, 646.

[3] Physiologische Psychologie, 4te Aufl., II, 288 ff.; for Dietze's full statement see *Phil. Stud.*, II, 362 ff.

[4] *Zeitschrift für Psychologie*, I, 1890, 99-107.

[5] Summarized by Wundt, Phys Psy., 4te Aufl., II, 431 ff.; for Wolfe's full statement see *Phil. Stud.*, III, 534 ff.

musical tones were aimed directly at the determination of this duration. In these experiments the ability to *recognize* a given tone was used as the test of the integrity of the memory-image instead of the ability to *reproduce* it which was used in the experiments of this paper. It is not surprising, therefore, that the duration found by Wolfe should be larger, extending to as much as sixty seconds. The fact that Wolfe's experiments were made with concentrated attention, and those of this paper with distracted attention, is also important, though single tones would not form many associative bonds, except perhaps with very musical subjects. The percentages of right answers are not directly comparable in the two studies, because of the greater opportunity for error with the groups of digits, but there is nothing overtly contradictory in them. The tendency of the digits to re-enter consciousness, observed by *S* and *D*, is undoubtedly the same that gives the periodic improvement of memory in Wolfe's curves.

X. On the Least Observable Interval Between Stimuli Addressed to Disparate Senses and to Different Organs of the Same Sense.

By Alice J. Hamlin.[1]

The figures commonly given by the text-books for this interval are taken from work done by Exner nearly twenty years ago and, so far as the writer is aware, since repeated only in part.[2] The object of the following experiments

[1] Student at the Summer School, 1894.

[2] Exner, *Pflüger's Archiv.*, XI, 1875, 403-432. The statements in the text-books leave it open to the reader to infer that the figures are for single pairs of stimuli, (a single visual stimulus, for example, followed by a single auditory stimulus)—such at least was the conception under which these experiments were undertaken. When, however, Exner's original paper was examined, it was found that his method, except in the case of separate stimuli to the two ears, was such as to give him a series of pairs of stimuli instead of a single pair (pp. 405, 419-20, 423, 426). This may be represented diagrammatically as follows, letting (*a*) stand for auditory and (*v*) for visual:

(Auditory first).	*av.*———	*av.*———	*av.*———	*av.*———	*av.*———	*av.*
(Visual first).	*va.*———	*va.*———	*va.*———	*va.*———	*va.*———	*va.*

In the writer's experiments, on the contrary, single pairs (or triplets) of stimuli were used without exception, *e. g.*, either *av* or *va*. The importance of this difference will appear in the discussion of results below. The work of von Tschisch (*Phil. Stud.*, II, 603), of Angell and Pierce (this Journal, IV, 528), and of Jastrow and